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EPA

Lasagna™ Public-Private Partnership

RTDF

Remediation Technologies Development Forum

RTDF Action Teams

Bioremediation Consortium

Permeable Reactive Barriers Action Team

IINERT Soil-Metals Action Team

Sediments Remediation Action Team

***In Situ* Flushing Action Team**

Phytoremediation of Organics Action Team

What Is the Lasagna™ Public-Private Partnership?

In early 1994, the U.S. Environmental Protection Agency (EPA) signed a Cooperative Research and Development Agreement with a private research consortium—consisting of Monsanto, DuPont, and General Electric—to jointly develop an integrated, *in situ* remedial technology, referred to as the Lasagna™ process. In 1995, with significant funding from the Department of Energy (DOE), a field experiment to test the Lasagna™ process was initiated at the DOE Paducah Gaseous Diffusion Plant in Kentucky. This collaborative effort between the federal government and industry evolved into one of seven Action Teams of the Remediation Technologies Development Forum (RTDF). The RTDF was established in 1992 by EPA to foster collaboration between the public and private sectors in developing innovative solutions to mutual hazardous waste problems.

What Is the Problem of Concern?

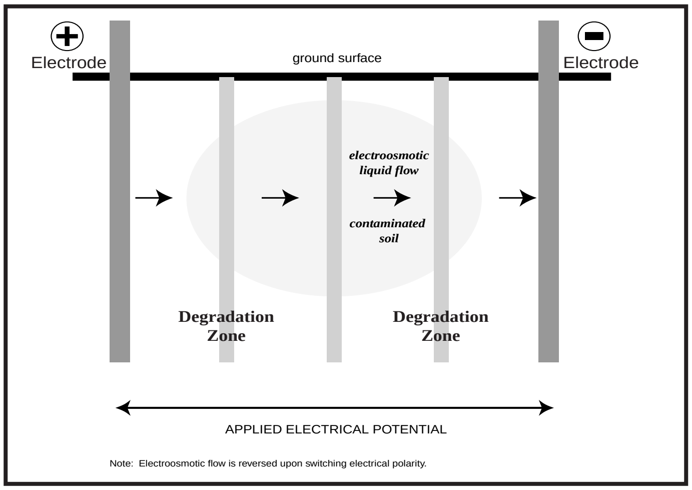
Contamination in low-permeability or heterogeneous soils poses a significant technical challenge to *in situ* remediation efforts. Difficulty in accessing the contaminants and delivering treatment reagents has rendered traditional technologies—such as vapor extraction and pump-and-treat—rather ineffective when applied to the low-permeability soils at many contaminated sites. Another major problem involves mixed wastes (organics plus heavy metals/radionuclides). The incompatibility of treatment methods for these two contrasting types of contaminants has created considerable difficulty in treating this type of waste.

What Is the Lasagna™ Process?

The Lasagna™ process, so named because of its treatment layers, combines electrokinetics (EK) with treatment zones that are installed directly in the contaminated soils to form an integrated *in situ* remedial process. Electrokinetics includes electroosmosis (EO, transport of water) and electromigration (EM, transport of ions). EO, used for years by civil engineers, is known for its effectiveness in moving water uniformly through low-permeability soils at very low power consumption. Conceptually, the Lasagna™ process would be used to treat organic and inorganic contaminants as well as mixed wastes.

The Lasagna™ process is designed to treat soil and ground-water contaminants completely *in situ*, without the use of injection or extraction wells. If successful, it could replace the more conventional methods for containing and treating contaminants in low-permeability soils. The schematic diagrams on the next page depict two typical configurations (horizontal and vertical) of the Lasagna™ process. Other variations also are possible. Treatment zones can be discrete or continuous (dispersed in the soil) or a combination of the two.

Vertical Configuration of the Lasagna™ Process



As the diagrams illustrate, the outer layers consist of positively or negatively charged electrodes. The electric field created by the electrodes moves contaminants in soil pore fluids into or through the treatment layers.

In situ decontamination using the Lasagna™ process can occur by:

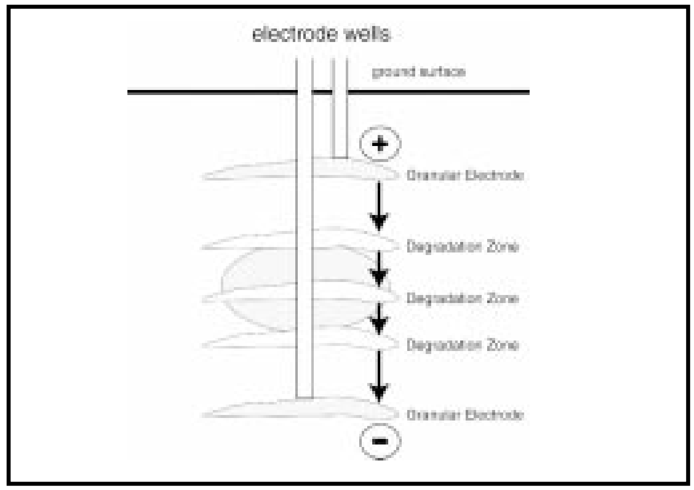
Creating zones in close proximity to one another throughout the contaminated soil region and converting them into sorption/degradation zones by introducing appropriate materials (*e.g.*, sorbents, catalytic agents, microbes, oxidants, buffers, etc.). Hydraulic fracturing and related technologies may provide an effective and low-cost means for creating such zones horizontally in the subsurface soil. The degradation zones can also be emplaced vertically, as depicted in the schematic above, using sheet piling, trenching, and slurry walls. Methods such as pneumatic fracturing, jet grouting, and soil mixing could be used to create dispersed or homogeneous treatment zones.

Utilizing electrokinetics to transport contaminants from the soil into the treatment zones for degradation. Locating these zones close to one another minimizes the time it takes for the contaminants to be moved by EK from one zone to the next. In the horizontal configuration, hydrofracturing can be used to place graphite or other granular, electrically conductive materials in zones above and below the contaminated soil area to form the electrodes in place. For highly nonpolar contaminants, surfactants can be introduced into the water or incorporated into the treatment zones to solubilize the organics. For mixed wastes, treatment zones containing mixed reagents or multiple zones containing different reagents could be used to handle organics and metals/radionuclides simultaneously or sequentially.

Recycling the cathode effluent (high pH) back to the anode side (low pH), which provides a convenient means for pH neutralization and water management. The electrical polarity can be periodically reversed, if needed, to minimize complications associated with long-term applications of one-directional EK processes. Polarity reversal also allows multiple passes of the contaminants through the treatment zones for complete sorption/degradation.

The orientation of the electrodes and treatment zones depends on the site/contaminant characteristics. In general,

Horizontal Configuration of the Lasagna™ Process



the vertical configuration is probably applicable to more shallow contamination (*i.e.*, within 50 feet of the ground surface), whereas the horizontal configuration, using hydraulic fracturing or related methods, is capable of treating much deeper contamination.

What Is the Mission of the Partnership?

The mission of the Lasagna™ Partnership—which includes private industry, DOE, and EPA—is to pool expertise and resources to advance the development of the Lasagna™ process to remediate organic and inorganic contaminants in low-permeability soils. The overall goal of the Partnership is to sufficiently develop the Lasagna™ technology so that it can be utilized for site remediation.

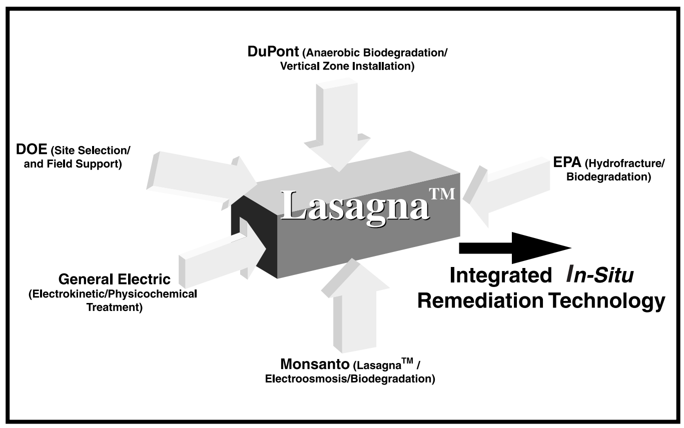
What Has Been Accomplished?

In the Phase I-Vertical field test, completed in 1995 at Paducah, the Lasagna™ process achieved a 98 percent removal of TCE, from a tight clay soil (*i.e.*, hydraulic conductivity $<10^{-7}$ cm/sec), with some samples showing greater than 99 percent removal. TCE soil levels were reduced from the 100 to 500 ppm range to an average concentration of 1 ppm. This success led to full-scale testing of the Lasagna™ process (called Phase IIA-Vertical), incorporating reactive treatment zones to destroy TCE *in situ*. The full-scale test began in August 1996 and covered an area measuring 30 feet by 21 feet by 45 feet deep. High levels of TCE in pre-test samples strongly indicated the presence of pure TCE droplets (Dense Non-Aqueous Phase Liquids or DNAPLs) in the soil. Two electrodes (one on each end of the test site) were used, with three treatment zones at 2- and 5-foot intervals to help determine the optimal spacing. Each electrode or treatment zone measured 21 feet across, 1.5 inches thick, and 45 feet deep.

Despite finding at least 30 times more TCE contamination than expected and encountering an undefined sand lens (at a depth of 20 to 25 feet) that may have caused unpredictable hydraulic movement at the test site, the test was successful. Samples taken after about 10 months of operation showed 99.8 percent TCE removal in the soil region bracketed between the 2-foot-spacing treatment zones. This corresponded to an average TCE level of 0.1 ppm, substantially lower than the Kentucky soil cleanup target. Two soil sections downstream of the last treatment zone showed about 70 percent TCE removal, clearly suggesting that cleanup was achieved. Well water samples and analysis of reaction products also suggested DNAPL movement and its *in situ* degradation by iron filings. Based on the test data, DuPont has determined that the cost of the Lasagna™ treatment is \$50 to \$100/yd^3 for cleanup of a 1-acre or larger site. As a result of this demonstration, DOE is pursuing regulatory approval through the CERCLA process to clean up the entire Solid Waste Management Unit using Lasagna™.

The University of Cincinnati, through a Cooperative Agreement funded by EPA, is conducting laboratory and field research on hydrofracturing and biodegradation to develop the horizontal configuration. This work, which has been performed in clean soils, has focused on developing durable electrical and fluid connections to the horizontal (hydraulic fracture) electrodes and treatment zones and solving the problem of gas generation in the electrodes. Six different horizontal test units have been installed at a clean site near Cincinnati. The survival of a methanotropic microorganism in a treatment zone is being examined while the electrodes above and below are energized to move water by electroosmotic processes. The treatment zone is composed of granular activated carbon, which was seeded with microorganisms and nutrients through hydrofracturing before it was installed. The microorganism was isolated from a group of organisms and was selected for its ability to degrade TCE. Two small-scale horizontal cells have been installed in TCE-contaminated soil at Rickenbacker Air National Guard Base (ANGB) in Columbus, Ohio. The treatment zones in one cell use reductive dechlorination (zero-valent iron); the other cell has a single biological treatment zone. A 30 percent reduction in TCE concentrations has been observed in soils in the biological treatment cell. Both cells are in operation and are being sampled periodically to track TCE concentrations and determine when treatment can be terminated. The infrastructure for two large-scale horizontal cells has been installed in TCE-contaminated soil at Offutt Air Force Base (AFB) in Omaha, Nebraska. The computer-controlled power supply, instrument building, and utilities are in place, and the materials to install the graphite electrodes and zero-valent iron treatment zones have been ordered.

Lasagna™ Partnership Members



What Are the Partners' Roles?

Each Partner brings particular knowledge and expertise, as well as contributes the resources necessary to complete the Partnership's research and development mission. The three companies share proprietary technologies and their collective understanding of EK, catalytic dechlorination, bioremediation, process simulation, and cost analysis to support development and evaluation of the Lasagna™ process. DOE brings to the project knowledge of EK and bioremediation and provides funding and analytical and field support for the studies at Paducah. EPA's National Risk Management Research Laboratory (NRMRL) in Cincinnati is leading the investigation of emplacement and operation of the horizontal configuration of the Lasagna™ process. In conjunction with the University of Cincinnati, NRMRL is using hydrofracturing to create electrodes and treatment zones in subsurface soils and is selecting microorganisms that can degrade contaminants and survive electroosmosis. NRMRL and the University of Cincinnati also are investigating the basic geochemistry of the Lasagna™ process to provide a sound basis for optimization. The Partnership is facilitated by Clean Sites, Inc., under a cooperative agreement with EPA's Technology Innovation Office, and by The Scientific Consulting Group.

What Activities Are Planned?

In the spring of 1996, the Partnership's Phase IIA-Vertical Lasagna™ demonstration was selected for inclusion in the federal government's Rapid Commercialization Initiative (RCI). Participation of California EPA, Southeastern States Energy Board, the Western Governors Association, and various state environmental agencies in RCI will help facilitate regulatory acceptance and widespread use of the Lasagna™ technology. Results from Phase IIA-Vertical and the subsequent cleanup (Phase IIB-Vertical) will be used to produce verified cost and performance data for the Lasagna™ process, which will also greatly increase its acceptance and use. Various treatment processes are currently being investigated in the laboratory to address other types of contaminants, such as DNAPLs, heavy metals, and mixed wastes. Additional test sites are being sought to further demonstrate the effectiveness of the technology. Monsanto also is actively working on the commercialization of the Lasagna™ technology through licensing and partnership agreements.

The work on gas generation and electrical/fluid connections for horizontal emplacements in clean soil was completed during the spring and summer of 1996. The horizontal field test at Rickenbacker ANGB will continue in 1997-1998 until treatment is completed. The horizontal test cells are scheduled for installation at Offutt AFB in the fall of 1997 and will operate during 1997-1998.

Who Are the Members of the Lasagna™ Partnership?

DuPont
General Electric
Monsanto

U.S. Department of Energy
U.S. Environmental Protection Agency

Additional organizations involved in the projects include Lockheed Martin Energy Systems, Nilex, API, CDM Federal, the University of Cincinnati, the State of Kentucky, and the U.S. Air Force.

Lasagna is a trademark of the Monsanto Company.

RTDF

Remediation Technologies Development Forum

Would You Like More Information?

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